Regional Stratification and Shear of the Various Streams Feeding the Philippine Straits

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LONG-TERM GOALS

To determine the impact of the regional oceanographic and atmospheric mean and variable conditions on Philippine Archipelago.

OBJECTIVES

To quantify the oceanographic stratification and shear and the corresponding intraseasonal, monsoonal, and ENSO variability controlling the boundary conditions of the Philippine Archipelago strait dynamics.

APPROACH

Regional CTD and Lowered ADCP [CTD/LADCP] surveys in coordination with Amy Ffield [Earth and Space Science].

WORK COMPLETED

Analysis of archival in situ and satellite observational data of the Philippine Archipelago region in preparation for the field research in 2007 and 2008.

RESULTS

A general introduction to the region in reference to the ONR DRI "Characterization and Modeling of Archipelago Strait Dynamics" was produced in August and September 2006. It is noted that funding for the program begun in the closing months of fy06, so the research is in theinitial information gathering phase.

Large bodies of water are often interconnected through narrow channels or sea straits. The exchanges of water, heat, salinity, and regional ecosystems through these straits influence the larger regional scale oceanography are governed by the complex physical processes within the sea straits. These processes govern the form the circulation and mixing environment within these constricted conduits, which in turn affect such economic factors as local fisheries, marine aquaculture and environment, coastal zone management, tourism, and marine safety of transit routes for commercial shipping inter-island transport. However, the localize dynamics of these straits are surprisingly poorly understood. Proper

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observations and description of oceanography of straits are needed to quantify the relevant physical processes. This would allow for more accurate simulation of the strait within ocean, climate and ecosystem models. To address these issues an ONR DRI entitled “Characterization and Modeling of Archipelago Strait Dynamics” was formed, with a target research area of the Philippines seas.

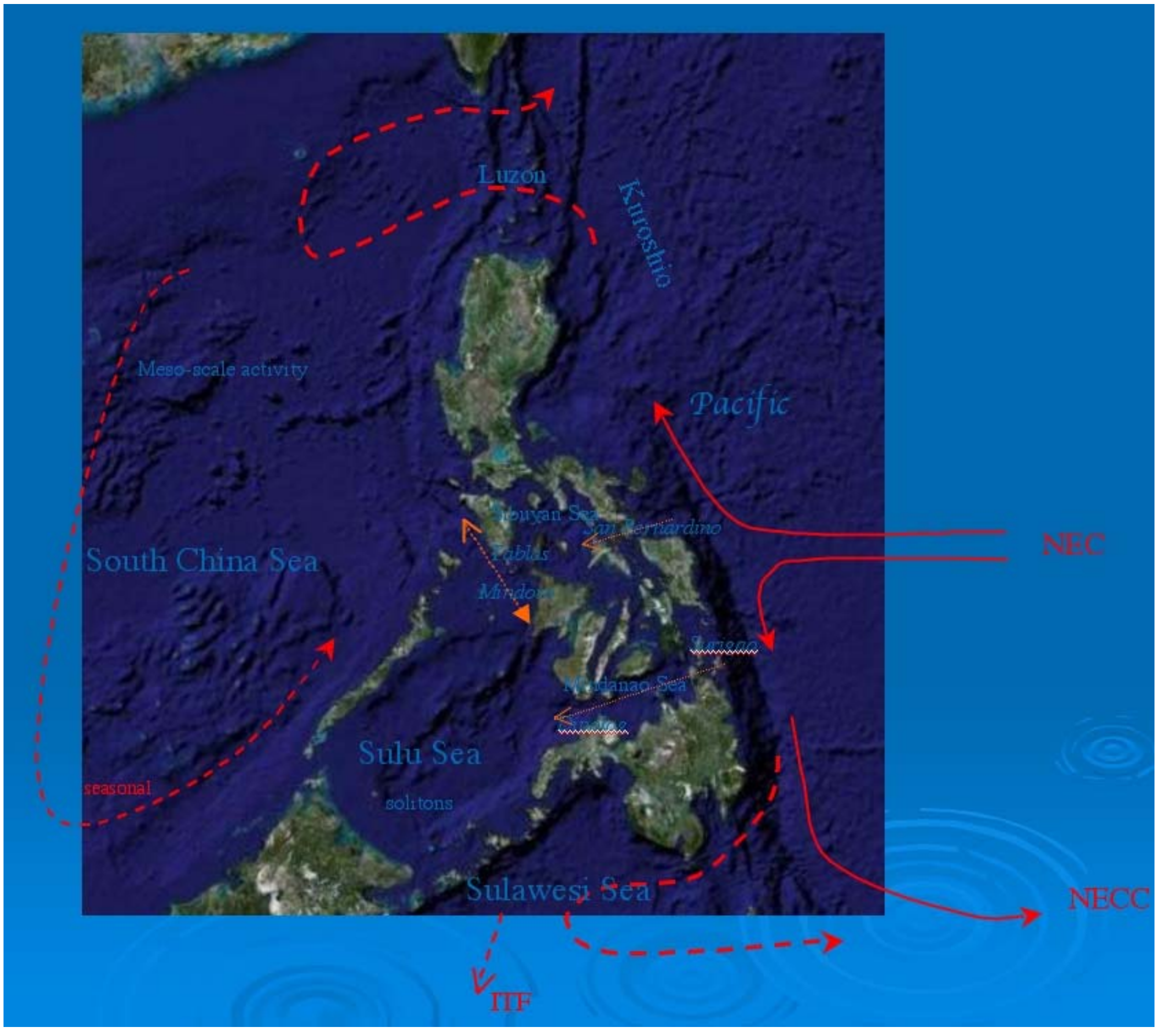

Figure 1: A map of the Philippine regions and schematic of surface current patterns. The western Pacific Equatorial currents and bifurcations are shown as solid red arrows; the intrusions of Pacific water into the South China Sea and Sulawesi Sea are shown as dashed red arrows; the flow within the primary straits of the Philippine Archipelago are shows as orange dotted arrows. The multitude of straits and seas within Philippine waters offer a wide variety of topographic conditions, including an assortment of channel widths and sill depths plus island distribution; connecting seas of varied shapes and depths, with a range of remote forcing attributes.

A number of potentially interesting straits can be identified within Philippine waters that would allow us to effectively advance our understanding of strait dynamics and their relationship to the larger regional scales. An appropriate strait for research would have the following attributes or boundary conditions: 1. complex undersea topography with a topographic sill of >300 m [so the throughflow waters are well stratified]; 2. a strong advective throughflow; 3. wind and the resultant Ekman transport that reverses sharply with monsoon season; 4. strong surface and internal tides. The Mindoro (365-m sill)/Tablas Strait (320-m sill) as the lead candidate site for the strait dynamic study. The Mindoro/Tablas straits include the connection of two large, dissimilar seas [South China Sea and the Sulu Sea] plus a "side" connection via Tablas Strait to a large, deep interior Philippine sea [Sibuyan Sea]. There are three sills of ~300-400 m depths. The southern most one may prove to be the most interesting in terms of energetic. All of this is up for discussion among the research group and the results of an exploratory regional CTD/LADCP survey scheduled for May-June 2007. A meeting of the research group for discussion of the development of the program and form of the 2007 regional survey will be held on 18-19 September 2006 at the Lamont-Doherty Earth Observatory.

Funding for the program begun in the closing months of fy06, so the research is in the very early stages, confined to information exchange among US and Philippine researchers. In preparation for the development of the ONR DRI "Characterization and Modeling of Archipelago Strait Dynamics", a brief introduction to the regional oceanography was prepared, a summary of which is as follows [see figure 1]: To the east of the Philippines is the western boundary of the open North Pacific. The North Equatorial Current impinges the coast of the Philippines where it splits or bifurcates into a northward flowing western boundary current, the origin of the Kuroshio, and a southward flowing western boundary current, the Mindanao Current. The continued northward path of the Kuroshio is complicated as part flows into the South China Sea via the Luzon Strait at the northern end of the Philippines. The Kuroshio intrusion into Luzon and the South China Sea seems not to be controlled by the western Pacific current, but rather by the cyclonic gyre within the northern South China Sea. The position and the strength of the cyclonic gyre is linked to the seasonal monsoon: the intrusion is most likely at the winter during the northern monsoon. The Mindanao branch of the bifurcation also follows a complex pathway. About 25% of the Mindanao Current enters the Indian Ocean as part of the Indonesian Throughflow, the rest curls back into the Pacific feeding the North Equatorial Countercurrent. The division between the two very different destinations of the Mindanao Current waters occurs to the south of the Philippines, in what is referred to as the Mindanao Eddy, a highly energetic circulation features over the Sangihe Ridge [sill ~1000 m] spanning the distance between the northeastern tip of Sulawesi to the southern end of Mindanao.

The North Equatorial Current bifurcation and associated geostrophic adjustment leads to an interesting spatial form of the pycnocline along the eastern coast of the Philippines. Seasonal and interannual variability of the bifurcation changes the boundary conditions along the eastern margins of the Philippines straits. The bifurcation of the North Equatorial Current along the eastern coast of the Philippines shifts northward with increasing depth: the mean latitude at the sea surface is 14.2°N, but at 600 m it is at 19.5°N. The inclination is steeper in July, gentler in December. When the Ekman transport is added, the southern limits of the surface bifurcation point shifts to 13.3°N. The depth averaged bifurcation varies in position from 14.8°N in July to 17.2°N in November/December.

To the west of the Philippines are the South China and the Sulu Seas. There are no observationally based time series spanning the monsoonal flow reversals along the western side of the Philippines. However model studies suggest that part of the Luzon Straits westward net annual transport may pass through the Mindoro Strait into the Sulu Sea and through the Karimata Strait into the Java Sea. It is uncertain if this water continues into the Indian Ocean, adding to the Indonesian Throughflow, or if it passes back to the Pacific along a path off the southern Philippines to enter in the North Equatorial Countercurrent. While the Mindoro and Karimata annual transports are unlikely to exceed 1 Sv they have a strong reversals with the season [with an amplitude of perhaps 3 Sv]. The monsoonal changing nature of the South China Sea and Sulu Sea is expected to alter the advective dynamics within Mindoro Strait. Additionally, the Sulu Sea is isolated from the surrounding seas at depths below ~400 m of the Mindoro Strait. This allows South China Sea thermocline water to spill into the depths of the Sulu Sea, to slowly replace the resident deep water made less dense by vertical mixing processes.

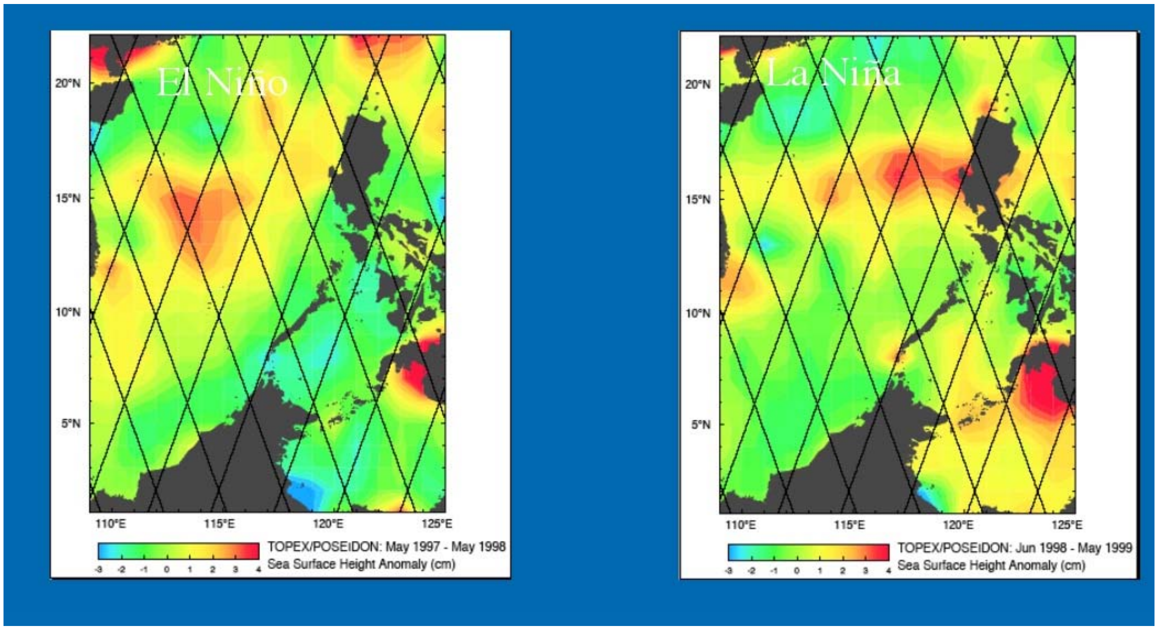

Figure 2 SSHA variability in SCS and Sulu Sea sector off the west cost of the Philippines is slightly reduced during El Niño relative to La Niña. This may mean less intraseasonal [<90 day] variability in the flow within Philippine Straits [e.g. Mindoro/Tablas] during El Niño

The South China and Sulu Seas have tidal height amplitudes of ~1 meter. Tides are mostly semidiurnal tide in the western Pacific and diurnal within the South China Sea, more of an even mix in the Sulu Sea. The energetic and phase difference of the tides across the varies seas surrounding the Philippines leads to strong tidally induced throughflow within the Philippine straits. Once manifestation of this are the large internal waves such as the solitons within the Sulu Sea produced near Pearl Bank, which separates very different tidal regimes of the Sulu Sea from the Sulawesi Sea. Differences in amplitude and phase cause strong tidal currents to oscillate across Pearl Bank. Solitons are also common in the northern end of the South China Sea, propagating westward from their formation between Taiwan and the Philippines.

IMPACT/APPLICATION

The analysis of archived observational data is used to design field work in 2007 and 2008 and to aid in the development and evaluation of ocean models.

TRANSITIONS

None

RELATED PROJECTS

None

REFERENCES

None

PUBLICATIONS

None

PATENTS

None

HONORS/AWARDS/PRIZED

Sc.D. *Honoris causa* University of Cape Town, South Africa, December 2005